

The use and care of **REAMERS**



The Use and Care of Reamers

This booklet, published by The Cleveland Twist Drill Company, is intended to aid in the proper use and care of reamers. Because of the factors involved in reaming, it is not possible to make this a complete treatise on the subject, but rather an introduction to the theories underlying the use of reamers.

This booklet is intended as a text book for distribution to colleges, technical and vocational schools, both in the United States and abroad. It can also be used by manufacturers with apprentice schools who will find it an excellent manual. Anyone who is interested is welcome to copies of this book.

The material in this booklet was taken from the "Metal Cutting Tool Handbook", published by the Metal Cutting Tool Institute, 405 Lexington Avenue, New York 17, New York.

We recommend that those who are interested in all phases of cutting tools should avail themselves of the Metal Cutting Tool Handbook. It includes technical information on drills, reamers, counterbores, taps and dies, milling cutters, hobs and gears, and broaching tools. In addition there is a section on other engineering data.



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Selection of Reamers

The factors that should influence the selection of reamers for a given job can be enumerated as follows:

1. Material to be reamed.
2. Diameter of hole.
3. Amount of stock to be removed.
4. Accuracy and finish desired.
5. First cost.
6. Maintenance costs.
7. Salvage value.

The material to be reamed has much to do with selecting the best type of reamer. It is evident that if the material is free cutting, reamers of fairly light construction can be used to produce holes of satisfactory quality. But, if the material is hard, tough, or stringy in texture, adequate provisions must be made to meet these conditions. The power required to drive reamers through given materials must be compensated for in their design, so that no undue deflection will take place.

Thus, Shell-Type Reamers can be used in comparatively small diameters for cutting free machining materials, but for hard or tough materials, Solid-Type Reamers are to be recommended, even for holes of fairly large size.

No definite range of sizes can be given here, because of the widely varying conditions that surround different jobs. It should be borne in mind, however, that when holes are to be finished by reaming to very close tolerances, no deflection whatever is permissible in the reamer itself.

Theoretically, a Shell Reamer Arbor should fully support the reamer so that it will not deflect, but in practice this is not always the case, because of wear of the arbor or the presence of burrs, dirt or other foreign materials. On production jobs where more or less unskilled operators are used, these factors must be taken into account.

The amount of stock to be removed has a direct influence on the necessary driving force and in turn on the strength and rigidity the reamers must possess. While the driving force is not necessarily proportional to the amount



of stock to be removed (as the frictional load is practically constant), the above statement is generally true.

While it is possible to produce reamed holes having a good finish, but poor accuracy, it may be said that, in general, accuracy and finish go together. Accuracy, in this case, takes into account tolerances on diameter, roundness, straightness, and absence of bell-mouth at ends of holes. To meet all of these conditions, it is necessary to use reamers with proper and adequate support for the cutting edges. Solid-Type Reamers should be used up to a point where the reamer is large enough in diameter to accommodate an arbor hole and yet leave sufficient wall thickness to fully support the cutting edges against deflection under load.

It is obvious that, as diameters of reamers increase, the first cost of solid-type, or even of Shell-Type Reamers with integral cutting edges, will eventually become prohibitive. The Inserted Blade and Adjustable Type of reamer then is available. Adjustable Reamers are designed to permit the user to set them to any desired diameter within the range of the adjustment. This adjustment permits them to be set to a special diameter, and also, when the reamers are worn, allows them to be set oversize, reground, and recleared. The high-speed steel blades may be replaced individually or in sets when necessary. For these reasons this type of reamer is particularly adapted for machine reaming on a production basis. However, in changing to the latter type, the matter of maintenance costs to provide continuous rigidity and accuracy must be closely studied. Experience has shown that, unless reconditioning is carefully and competently done, the first and replacement cost advantages of these reamers are lost.

When using solid chucking reamers on production work, quite often it will be found that reaming costs are high due to the necessity of discarding reamers because they have been worn undersize. The expansion feature of the Expansion Machine Reamer is designed to maintain the initial size by compensating for wear on the cutting end. When the reamer is worn it may be expanded oversize, reground to size, and recleared. Expansion screws should never be loosened in an attempt to use the reamers for a size smaller than that to which the tools were originally circle ground.



The salvage value of Solid Type Reamers will depend largely on the products that are manufactured and on the variety of sizes of holes. In some shops it is possible to re-grind reamers that are worn undersize for a smaller size hole, where they can again be used with full wearing life. This can only be done where the difference in sizes comes within the practical regrinding range.

The choice as to whether a Straight-Fluted or Spiral-Fluted Reamer shall be used is largely a personal one with the user. Theoretically, a spiral-fluted reamer is less likely to chatter than is a straight-fluted tool, but this is not always borne out in practice, due to the multiplicity of other factors involved.

In general, right-hand spiral reamers cut slightly more freely than straight-fluted or left-hand spiral tools, and because of their chip clearing ability have a slight advantage in the reaming of blind holes. However, in screw machine work, if the blind holes are not too deep, left-hand spiral tools work satisfactorily.

Oil Feeding Reamers are used where it is necessary to provide a means of getting coolant to the reamer cutting edges in cases where the cutting oil cannot naturally flow to the cutting edges.

One type of Oil Feeding Reamer is illustrated in Fig. 1. This type of feed is excellent in the reaming of blind holes where the oil fills up the hole ahead of the reamer and forces coolant back through the flutes carrying away heat and chips.

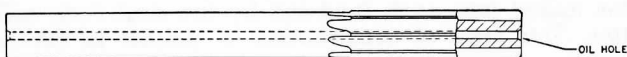


Fig. 1

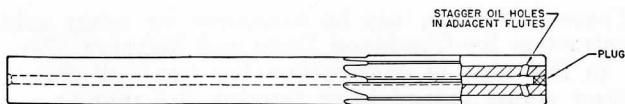


Fig. 2

Oil Feeding Reamers

Fig. 2 shows an Oil Feeding Reamer with the through hole blocked off, and cross-holes placed in the flutes. This



arrangement provides an ample flow of coolant to the cutting edges in cases where horizontal reaming is done to considerable depths and coolant cannot be directed to the cutting edges. In the vertical reaming of a through hole, the natural gravity feed of the coolant provides enough flow for a regular type reamer.

COMBINED DRILLS AND REAMERS

Quite often when holes must be drilled and reamed, the two operations can be performed with a single tool, eliminating a second handling of the part to be machined. Such a tool is known as a Combined Drill and Reamer. As the drill portion should be entirely through the part before the reamer section starts to cut, this type of tool is usually used only on shallow holes. This is most important, and in giving specifications for the tool the drill diameter should always be larger than the depth of the hole to be drilled.

These tools are usually made with either of two types of construction.



Fig. 3. Step Construction

In step construction shown in Fig. 3, two drill flutes are milled the full length of the tool. The drill section is of slightly smaller diameter than the reamer section and the drill margins extend only the length of this drill section.

The reamer section consists of one, two, or three reamer flutes milled into each land left by the drill flute milling cutter. This type of construction is subject to the same difficulties in regrinding that are encountered with step drills.

These difficulties may be overcome by using subland construction for Combined Drills and Reamers. (See Fig. 4.) In this type of construction the two drill flutes and cutting edges extend back through the reamer portion the full length of the tool. The reamer cutting edges are in addition to these and start back a suitable distance from the drill point. This type of construction usually makes it necessary to employ two less reamer cutting edges than are used with step construction.



In both step and subland construction the stock left for reaming should be about the same as though separate drills and reamers were used.



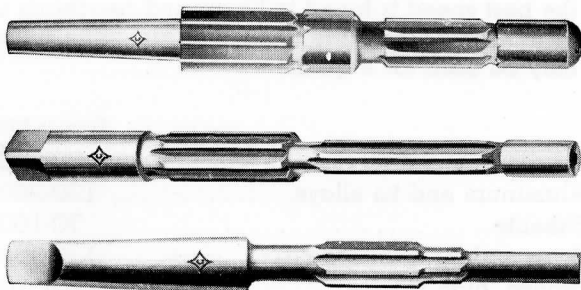
Fig. 4. Subland Construction

MULTIPLE DIAMETER REAMERS

Quite often it is necessary to ream two or more coaxial holes of different diameters. If a separate reamer is used for each hole several operations are necessary and it is difficult to keep the holes in line. The use of a multiple diameter reamer permits the operations to be performed all at one time and insures alignment of the holes.

Quite often each reaming section is preceded by a pilot section to bear in either the drilled holes or in bushings in the fixture. It is usually found best to design the tool so that all reaming sections start to cut at the same time. Due to the distance between successive reamer sections, step construction is employed except in very rare cases.

Below are shown several typical multiple diameter reamers:



Typical Multiple Diameter Reamers



The Use of Reamers

The conditions under which reamers are used and the results which are desired vary so widely that it is impossible to set up any guide to cover each possible combination. A few of the variables which affect reamer cutting action are listed below:

1. Speed.
2. Feed.
3. Use of guide bushings.
4. Material.
5. Condition of machine.
6. Rigidity of set-up.
7. Rake of cutting edges.
8. Clearance of reamer.
9. Amount of stock to be removed.
10. Finish required.
11. Tolerance of hole.

However, there are certain general principles which should be kept in mind.

SPEEDS

The most efficient speed for machine reaming is closely tied in with the type of material being reamed, the rigidity of the set-up, and the tolerance or finish required. Quite often the best speed is found to lie around two-thirds of the speed used for drilling the same material. The following table may be used for a guide:

	Speed in F.P.M.
Magnesium and its alloys.....	170-270
Aluminum and its alloys.....	130-200
Bakelite.....	70-100
Brass and Bronze, ordinary.....	130-200
Bronze, high tensile.....	50- 70
Monel Metal.....	25- 35
Cast Iron, soft.....	70-100



Speed in F. P. M.

Cast Iron, hard.....	50- 70
Cast Iron, chilled.....	20- 30
Malleable Iron.....	50- 60
Steel, Machinery .2C to .3C.....	50- 70
Steel, Annealed .4C to .5C.....	40- 50
Steel, Tool, 1.2C.....	35- 40
Steel, Alloy.....	35- 40
Steel, Automotive Forgings.....	35- 40
Steel, Alloy 300-400 Brinell.....	20- 30
Steel, Free Machining Stainless.....	40- 50
Steel, Hard Stainless.....	20- 30

A lack of rigidity in the set-up may necessitate slower speeds, while occasionally a very compact, rigid operation may permit still higher speeds.

When close tolerances and a fine finish are required it is usually found necessary to finish ream at considerably slower speeds.

In general, reamers do not work well when they chatter. Consequently, one of the primary considerations in selecting a speed is to stay low enough to eliminate all chatter. There are other ways of reducing this chatter which will be considered later, but this one rule holds true: **SPEEDS MUST NOT BE SO HIGH AS TO PERMIT CHATTER.**

FEEDS

In reaming, feeds are usually higher than those used for drilling. The amount of feed may vary with the material, but a good starting point would be between .0015" and .004" per flute per revolution. Too low a feed may result in glazing, excessive wear, and, occasionally, chatter. Too high a feed tends to reduce the accuracy of the hole and may also lower the quality of the finish. The basic idea is to use as high a feed as possible and still produce the required finish and accuracy.



AMOUNT OF STOCK REMOVED

For similar reasons, insufficient stock for reaming may result in a burnishing rather than a cutting action. It is very difficult to generalize on this phase as it is closely tied in with type of material, feed, finish required, depth of hole, and chip capacity of the reamer. For machine reaming, .010" on a $\frac{1}{4}$ " hole, .015" on a $\frac{1}{2}$ " hole, up to .025" on $1\frac{1}{2}$ " hole, seems a good starting point. For hand reaming, stock allowances are much smaller, partly because of the difficulty in forcing the reamer through greater stock. A common allowance is .001" to .003".

THE USE OF BUSHINGS

The use of bushings as guides for reamers is of great help. The ideal job would employ a fixed jig and bushing with a fixed spindle and a minimum of overhang. It is particularly important when using bushings that the spindle be accurately aligned with the bushing in order to prevent the reamer from hitting the top of the hardened bushing. In radial drill presses or in table presses equipped with sliding jigs, great care must be used. Sometimes bronze or fibre caps are placed over the bushings to act as a lead-in feature, but even this will not protect the reamer unless the tool is properly centered in the bushing.

The same problem arises if work is reamed on a table press without a bushing. The use of a short entering taper on the front of the reamer, or in some cases a short pilot section, may be of help in leading the reamer into the hole. However, the practice of using a reamer as a locating device and forcing it to drag the work over into alignment is not good, and is likely to result in excessive wear or chipped edges of the reamer.

When holes are to be located at exact distances from some point or some other hole, the only sure method is to do the reaming in jigs or fixtures. In such jigs or fixtures

the work is located and held securely, and the reamer is guided in bushings that are set in exact relation to locating points in the work.

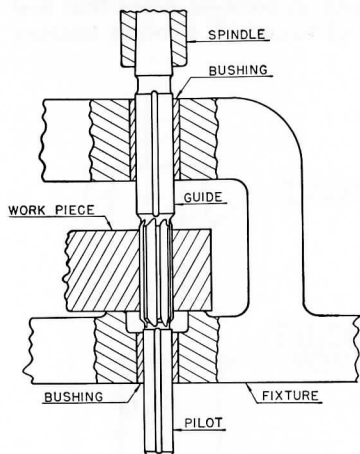


Fig. 5

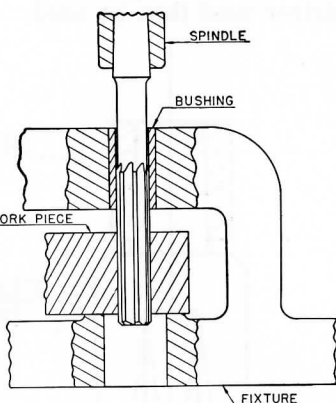


Fig. 6

Use of Guiding Bushings

For this type of reaming the ideal arrangement is to guide the reamer on both sides of the work, especially if the hole is comparatively long. Fig. 5 illustrates a typical set-up. A special piloted reamer is required for this purpose. Guide bushings should fit snugly to the pilots, but should not be so tight as to seize and bind. Pilots should be grooved throughout their length. These grooves serve the double purpose of permitting the cutting fluid to lubricate the pilots and to scavenge any chips that tend to wedge between the pilots and bushings.

If the holes to be reamed are short, the reamer may be guided at the entering side of the hole only. The guide bushing then may be made to fit the outside diameter of the reamer flute as illustrated in Fig. 6.

For either of these types of applications a rigid drive is satisfactory, because any misalignment of the machine spindle and the work tends to correct itself by means of the guiding bushings. By a rigid drive we mean one where the reamer shank is held directly and rigidly in the machine spindle.



If, on the other hand, the reamer is to guide itself into a previously made hole, a rigid drive is no longer satisfactory, because any existing misalignment of the machine spindle with the work will result in reamed holes that are bell-mouthed, tapered, or out of round. A floating reamer driver must then be used.

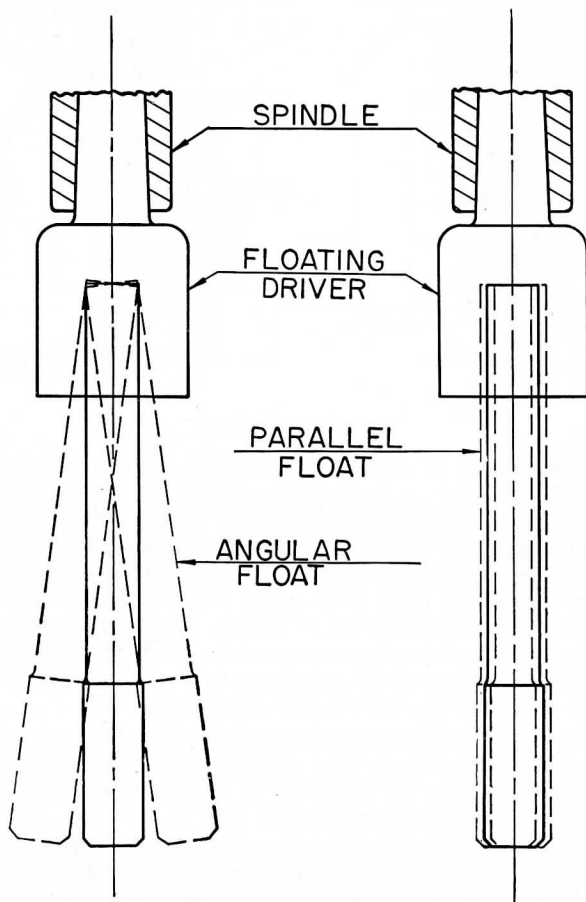


Fig. 7. Movement of Floating Drivers

Various types of floating drivers are in use, each possessing individual merits. Some types permit angular rela-



tion between the center lines of the driving spindle and the reamer. Others permit side movement of the axis of the reamer with that of the driving spindle, the two being parallel. Still others combine these two features.

The two principles that must be embodied in satisfactory floating reamer drivers are illustrated in Fig. 7. At the left are shown some of the angular positions that the reamer must be permitted to assume. At the right is illustrated what might be called parallel floating. Here the reamer axis may move away from the spindle axis while the two are in parallel.

The ideal floating driver must be able to do both of these. In other words, it must be able to adjust itself to misalignment of both types and in all positions throughout its circle of rotation. The amount of permissible angular or parallel float should be adjusted to cover the greatest amount of misalignment that is likely to occur on any given job.

HAND REAMING

Hand Reamers are made of both Carbon and High-Speed steel, and, as the name implies, are ordinarily used by hand for final sizing of holes. The square on the shank end is suitable for holding in a tap wrench or vise, depending on whether the reamer or work is rotated.

Expansion Hand Reamers are often used where it is necessary to enlarge a hole slightly in order to secure the necessary fit. Such an operation is quite common in maintenance or assembly work. Expansion reamers are usually made with an adjusting screw by means of which the reamer can be expanded slightly to the exact size required. Such reamers are regularly made with slightly undersized pilots which guide the reamer and help to hold it in alignment with the hole to be reamed. These reamers are ground with a starting taper on the flutes which provides easy entry of the reamer into the hole.

These reamers are designed to cut a small amount over nominal size for fitting purposes, and their limits of expansion are sufficient to accomplish this. Expansion Hand



Reamers often are broken in attempting to expand them an amount beyond that for which they were designed. This limit of expansion will vary, depending upon the exact design of the tool, but the following table will give a general indication:

Size of Reamer	Limit of Expansion
$\frac{1}{4}"$ to $\frac{15}{32}"$	Plus .006 inch
$\frac{1}{2}"$ to $\frac{31}{32}"$	Plus .010 inch
1" to $1\frac{1}{2}"$	Plus .012 inch
$1\frac{9}{16}"$ to 2"	Plus .015 inch

If an intermittent cut is encountered, such as a keyway, the use of the lefthand spiral fluted tools will be found helpful.

Adjustable Hand Reamers are designed to fill the needs of the user who has a few occasional holes of odd sizes to ream. This reamer has removable, replaceable blades which fit into slots having tapered bottoms. These cutting blades are usually made of carbon steel, but quite often are available made of high-speed steel. They are held in place by two locking nuts, and adjustment is made by loosening one nut while tightening the other. Due to their comparatively wide range of adjustment they find particular use in garages, repair shops, and tool rooms, since a single set of reamers will cover the complete range of hole sizes ordinarily encountered in reaming. They are usually designed with enough adjustment so that about twenty reamers are required to cover all hole sizes from about $\frac{1}{4}"$ to 3".

The cutting end of a Hand Reamer is ground with a starting taper to provide easy entry of the reamer into the hole.

When the work piece is reasonably rigid, hand reaming may be performed by rotating the reamer by means of a double end tap wrench applied to the driving square. This type of wrench, which permits a balanced drive, should always be used in preference to a single-end wrench. The use of single-end wrenches makes it almost impossible to apply torque without disturbing the alignment of the reamer and the hole.



The reamer should be rotated slowly and *evenly*, allowing it to align itself with the hole to be reamed. Wrenches should be large enough to permit a steady torque which will help to control vibration and chatter. The feed should be steady and large compared to the feed used in machine reamers. Feeds up to one quarter of the reamer diameter per revolution are not at all unusual.

In cases where the work piece is small enough to be handled with ease, it is often advisable to place the reamer vertically in a vise and rotate the work down over the reamer by hand. If the work is quite light it may not have enough mass to dampen vibrations. In such cases a holding device for the work may be employed which will add weight to the part to be reamed. This holding device should have two opposite handles on it, large enough in diameter to permit a steady controlled torque.

In cases where there is a large quantity of light parts to be reamed, the reamer is often mounted horizontally in a reaming machine. Most reaming machines are essentially chucks mounted on a motor-driven gear reducer. This drives the reamer at the necessary slow speed. The work piece is fed slowly and steadily over the reamer.

In all the hand reaming done by any of the methods described, with solid, expansion, or adjustable reamers, the reamer should *never* be rotated backwards to remove it from the hole, for this results in premature dulling of the reamer. If possible, it should be passed on through the hole and removed from the far side without stopping the rotation. If this is not possible, it should be withdrawn without stopping the *forward* rotation.

THE USE OF REAMERS IN TURRET LATHES AND HAND OR AUTOMATIC SCREW MACHINES

When using a reamer in turret lathes, hand or automatic screw machines, certain problems come up, due to the fact that the reamer is stationary and the work revolves. This is directly the opposite of the condition normally encountered in drill press operation.

Theoretically, in this type of reaming the axis of the reamer coincides with the axis of the machine spindle, and no difficulty should be encountered. However, in



actual practice, this condition seldom exists. It probably would be wise to assume that it never exists and to expect the presence of misalignment on jobs of this nature.

The misalignment is of two distinct types, illustrated in the five accompanying illustrations. Fig. 8 shows a case of true alignment.

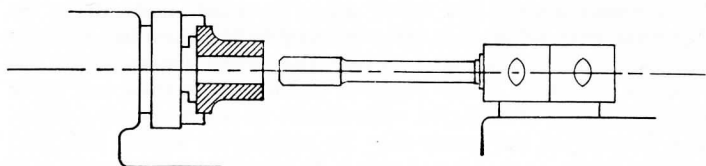


Fig. 8. True Alignment

In Fig. 9 is shown a case where the axis of the reamer is parallel to the axis of the spindle, but has been lowered slightly.

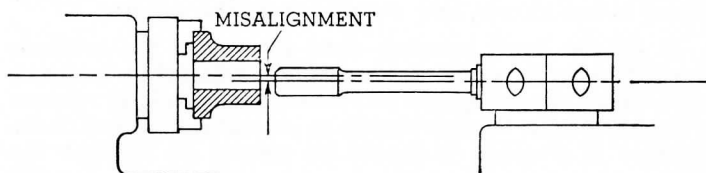


Fig. 9. Parallel Misalignment

In Fig. 10 the shank of the reamer is in line with the spindle, but the reamer has been clamped at a slight angle.

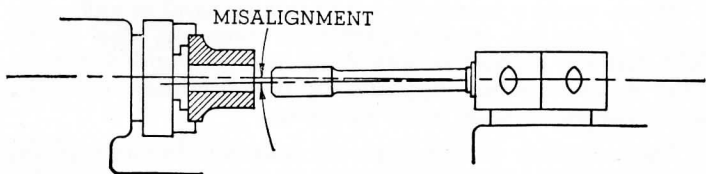


Fig. 10. Angular Misalignment



In actual practice both of these errors are often present at the same time in a single set-up. Such misalignment can be caused by a combination of several things.

1. Worn ways on the machine.
2. Worn or dirty holes in tool clamp.
3. Worn or dirty sleeves.
4. Improper leveling of machine.
5. Improper location or adjustment of tool slides.
6. Errors in indexing mechanism.

The use of a conventional reamer held rigidly in such a machine quite often results in poor finish and oversize holes, particularly in the start of the hole. Such holes are usually called "bell-mouthed."

In Fig. 11 is shown the case of reamer held at an angle to the spindle of the machine. As this reamer is fed into the work, the lower flute **A** will bear harder and harder against the wall of the reamed hole. This results in a scraping action by this flute which causes an oversize hole. The pressure also quite often causes a building up on this flute. When the pressure gets too high, this built-up portion breaks loose, causing gouges and tears in the reamed surface.

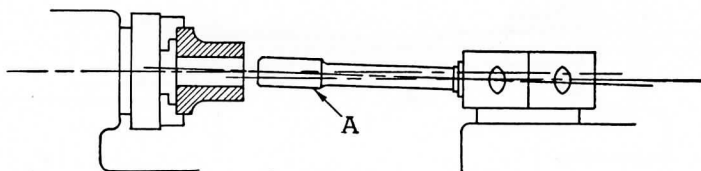


Fig. 11

There are several means available to eliminate these torn, oversize holes. The first is to make corrections on the machine and tool holders. It is comparatively simple to make some of these corrections, such as cleaning tool holders, replacing worn sleeves or bushings, and relocating some types of tool holders. Others, such as correcting mis-indexing on a turret lathe or multi-spindle automatic, may require a great deal of time.



The second method is to use floating holders for reamers. There are many kinds and designs of floating holders. Some correct for angular error only. Some correct for a parallel misalignment only, while some correct for both. Besides varying in function and design, these different floating holders also vary in their inherent rigidity. The problem in such holders is to allow movement in certain directions while restricting it in others. Naturally, this is not accomplished in the same manner in all designs, and the rigidity of different types of holders, whether floating or not, varies considerably.

The presence of slight errors in the machine does not necessarily mean that floating holders must be used. It must be remembered that the looseness in the machine plus the flexibility in the shank of the reamer provide some float. Also, on some types of machines, it is comparatively simple to insert blank bushings in the tool holder and rebores them from the head-stock. On other machines, adjustable rather than floating holders may be used.

This oversize condition is not always cured by the use of floating holders alone. In Fig. 12 is shown the case of a turret which has worn low and an attempt to correct this condition through the use of a simple pin drive float.

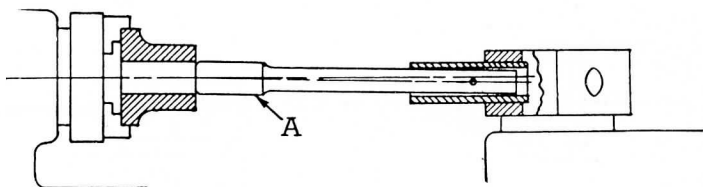


Fig. 12

Such a float allows the reamer to tilt slightly, but does not permit the shank of the reamer to move up or down or sideways. It will be noted that as the reamer feeds into the work the pressure will build up on the lower flute **A** as before, still causing oversize and torn holes.

In order to overcome this condition it is sometimes necessary to grind back taper on the reamer. While the use of back taper on reamers often will completely eliminate these rough, oversize holes, it must be remembered that



this back taper reduces the reamer life, particularly on close tolerance holes. This special back taper varies between .001" and .005" per inch of flute. Tapers such as these are far in excess of the very slight taper which has been found best for stock reamers designed to do the average reaming job. The figure of .005", in particular, seems excessive, and in the interest of economy the back taper should be kept as low as possible without interfering with the required hole size and finish.

REAMING OF TAPERED HOLES

The reaming of tapered holes has always presented a problem in reamer design and operation because of the very nature of the work to be performed. Usually one starts out with a drilled or bored hole of uniform diameter throughout. The diameter of this hole is slightly smaller than the finished diameter of the small end of the tapered hole to be produced.

The operation of taper reaming now consists of greatly enlarging one end of this hole, with this enlargement gradually decreasing towards the other end. This means that the Taper Reamer, instead of being a finishing tool, in reality becomes a tool for heavy stock removal, and further, that this tool at the finish of the operation is engaged in the cut thruout its entire length.

On account of the large amount of stock to be removed, and on account of the length of the cut, reamers are subjected to much greater torsional strains than the ordinary straight reamer that cuts on the end only. The tendency, therefore, is to chatter, with consequent poor finish or actual destruction of the reamer. The greater the taper, the worse these conditions will become.

Taper Reamers must, therefore, be constructed as sturdily as possible. Cutting edges must be adequately backed up, and flutes must be sufficiently large, with well rounded bottoms.

For machine reaming, it has been found that a reamer having few flutes, and with cutting edges at a large spiral angle with the axis, is by far the best. The flutes may vary in numbers from two to five in the ordinary range of sizes of reamers.



The spiral angle should be about forty-five degrees. A greater spiral angle than this does not tend to improve the quality of the cut, but does materially increase the amount of end pressure required to feed the reamer into the work.

It should be realized, however, that reamers with a fast left-hand spiral and right-hand cut tend to crowd the chips ahead of themselves. For this reason this design is not usually satisfactory for blind holes. For such holes, roughing reamers are often made of flat construction with little or no spiral angle.

It should be remembered that steep spiral Taper Reamers cannot be used on hand operations on account of the end pressure required, but for machine operations this is by far outweighed by smoothness of operation, better quality of work, and longer reamer life. These reamers must be used with power feeds for satisfactory results. For hand operation, Taper Reamers with straight flutes, or with about ten degrees of spiral opposite in direction to that of the cut, are recommended.

RIGIDITY

Any lack of rigidity in the holder tends to promote chatter. This chatter may exist only at the start of the hole as the reamer centers itself. In general, reamers do not work well when they chatter. Carbide Tipped Reamers, in particular, cannot stand even this momentary chatter at the start of the hole. It is quite likely to result in a chipping of the cutting corners.

Chatter may be caused by lack of rigidity in the machine, in the fixture, or in the work itself, or it may be caused by improper design of the reamer. The reamer must, therefore, be so designed that it not only will overcome chatter on its own account, but will help to counteract the lack of rigidity in the machine, fixture, or work piece.

If the hole to be reamed is fairly large in diameter, is short, and is near the outside surface of the work, the tendency to chatter can be more easily overcome, because it permits the use of a short reamer of comparatively large cross section. If, on the other hand, the hole is small in diameter, is long or inaccessible, the solution is far more difficult. The remedy usually is to make the reamer with unevenly spaced flutes, or with spiral flutes, or to provide



pilots for support at one or both ends of the flutes. Sometimes a combination of these features will give the desired results.

The object of unevenly spacing the flutes is to break up any tendency to synchronize slippage and torsional deflection. Chatter due to these causes is well known to reamer users.

Spiral flutes sometimes accomplish the same object even more effectively than uneven spacing. The thing to remember here is that the reamer must, if possible, have enough spiral so that two or more flutes overlap in the length of the hole being reamed. On the other hand, the spiral angle should not be more than necessary, because the steeper the spiral angle the more end pressure is required to feed the reamer through the work. Reamers for reaming tapered holes are an exception to the latter recommendation, because best results are obtained with a very steep spiral. The direction of spiral should be opposite to that of the cut, to prevent the reamer from pulling itself through, ahead of the feed.

Pilots are provided so that the reamer can be held in alignment, and can be supported as close to the work as possible. Sometimes the reamer is piloted in the work itself, but it is preferable to support it in the fixture by means of hardened and ground bushings. The diameters of pilots should always be kept as large as possible, to provide the greatest possible amount of rigidity to the reamer, and to prevent torsional deflection and chatter.

Chatter may be reduced in several ways, some of which are listed below:

1. Reducing the speed.
2. Varying the speed.
3. Increasing the rigidity of the tool holder thru reduction or even removal of the float.
4. Introduction of a small chamfer at the start of the hole before reaming.
5. Use of a piloted reamer.
6. Reducing the angle of clearance.

There are probably many other methods of reducing chatter; if maximum economy and a good finish are wanted, chatter must be eliminated.



COOLANTS FOR REAMING

In reaming, the emphasis is usually on finish, and a coolant is normally chosen for this purpose rather than for cooling. Quite often this may mean a change from that recommended for drilling, but in general the following list will be found to be satisfactory:

Aluminum and its alloys: Soluble oil, kerosene and lard oil compounds, light non-viscous neutral oil, kerosene and soluble oil mixtures.

Brass: Dry, soluble oil, kerosene and lard oil compounds, light non-viscous neutral oil.

Copper: Soluble oil, winter-strained lard oil, oleic acid compounds.

Cast Iron: Dry or with a jet of compressed air for a cooling medium.

Malleable Iron: Soluble oil, non-viscous neutral oil.

Monel Metal: Soluble oil, sulfurized mineral oil.

Steel, ordinary: Soluble oil, sulfurized oil, high Extreme Pressure value mineral oil.

Steel, very hard and refractory: Soluble oil, sulfurized oil, turpentine.

Steel, Stainless: Soluble oil, sulfurized mineral oil.

Wrought Iron: Soluble oil, sulfurized oil, high animal oil content mineral oil compound.

THE USE OF CARBIDE TIPPED REAMERS

In order to obtain maximum economy the user of Carbide Tipped Reamers should follow the general suggestions for the use of reamers already specified. In addition, there are a few special considerations which should be given to carbide tipped tools. Suggestions for regrinding of Carbide Tipped Reamers will be found on succeeding pages.

Speeds

The very high surface speeds which have been found necessary for turning operations with carbide tools present some difficulties if applied to reamers. In lathe work, the cutting tool may usually be made of any desired cross-



section and held in a large rigid tool-post with a minimum of overhang. In reaming, however, the size of the hole limits the cross-section of the tool, and usually considerable overhang is required. Both of these result in a loss of rigidity which is so necessary with very high surface speeds if chatter is to be avoided.

As already emphasized, reamers do not work well when they chatter. Carbide Tipped Reamers in particular cannot stand even a momentary chatter at the start of a hole, as such a vibration is likely to chip the cutting edges. Consequently, the primary consideration in selecting a speed is to **STAY LOW ENOUGH TO ELIMINATE ALL CHATTER.**

Rigidity

Carbide Reamers work best when well supported with a minimum of overhang. Any lack of rigidity in the set-up may result in a momentary vibration which may cause flaking and chipping of the carbide tips.

CAUSE OF BREAKAGE OR EXCESSIVE WEAR OF REAMERS

1. Dirt or burrs in spindle or socket in which reamer is held.
2. Misalignment of any two or more parts of the set-up. If this condition exists, a bell-mouthed hole plus excessive wear of reamer lands can result.
3. Lack of chip space in set-up or flutes of the reamer.
4. Too fast or too slow speeds.
5. Too much or too little feed.
6. Poor machining material.
7. Wrong type of coolant.
8. No lubricant between guide bushing and reamer.
9. Lack of lubricant.
10. Bottoming in blind holes.
11. Lack of sufficient stock to ream.
12. Too much stock to ream.
13. Entering work too fast.



14. Badly drilled holes.

Drilled holes must not be too rough, tapered, or bell-mouthed. Bell-mouthed holes may cause the reamer to wedge rather than cut.

15. Faulty sharpening.

Faulty sharpening may consist of: Improperly ground clearance on the cutting edges; grinding cracks due to too fast and heavy grind; unbalanced sharpening of cutting edges, causing one or two flutes of the reamer to take the entire cutting load; and saw-tooth cutting edges from too coarse a grind and incorrect end-cutting angle.

16. Poor handling of reamer.

17. Oversize or undersize bushings.

18. Chattering of reamer.

19. Lack of rigidity in machine or work holder.

20. Improperly designed reamer for the job.

REAMER REGRINDING

In obtaining maximum economy from reamers, the same principles apply as in the case of most other cutting tools. One of these principles is not to allow a tool to become too dull. It is best practice to regrind the chamfer on a reamer long before it exhibits excessive wear or refuses to cut. This sharpening is usually restricted to the entering taper or chamfer. It can be done on almost any tool and cutter grinder. Care must be taken so that each flute is ground exactly even; i.e., all cutting surfaces must be concentric, or the tool is likely to cut oversize.

Sharpening the chamfer on a reamer by hand is not recommended as it is practically impossible to keep the cutting edges even.

The accompanying illustrations show two common types of grinds used on reamers.

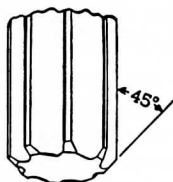


Fig. 13.
Ordinary reamer
point for most jobs.

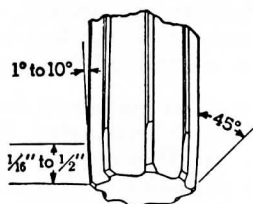


Fig. 14. Hand reamer grind
also used on some machine
reamer applications to obtain
required finish or tolerance.

On left-hand spiral tools it is important that the reamer be ground so as to leave a positive effective rake angle. This can best be done by reducing the 45° angle shown in Fig. 13 to about 30° , or even less. If the reamer has a very high left-hand spiral angle (20° or more), a grind similar to Fig. 14 usually is used.

Occasionally it is desirable to eliminate the chamfer and to grind the reamer to cut square across the end. Reamers sharpened in this manner have a cutting action much like that of an end mill. Reamers ground with a square end-cut are sometimes required to correct a bent or misaligned hole. Quite often this type of square end-cut is required to bottom a hole or to produce a square shoulder. Figs. 15, 16 and 17 show three separate types of square end-cutting grinds for use on reamers:



Fig. 15
Square End-Cut
to Bottom of Flutes

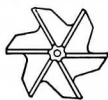


Fig. 16
Square End-Cut
to Center Hole



Fig. 17
Square End-Cut
to Center

The type of grind shown in Fig. 15 which cuts to the bottom of the flutes only, is relatively simple to apply to



any reamer and should always be specified when it is unnecessary for the tool to cut to a smaller diameter than can be accommodated by the ordinary depth of flute.

When it is necessary for the reamer to cut on its end to a still smaller diameter, the tool can be ground as shown in Fig. 16. This type of grind, which permits facing down to the diameter of the center hole, is more complicated and requires additional notching on the end. This type of grind should not be specified when the grind shown in Fig. 15 can be used.

The grind shown in Fig. 17 is designed to permit facing to the extreme center of the reamer. It will be noticed that two of the flutes cut to the extreme center; in order to grind a reamer in this manner the complete center hole must be removed and additional rather complex notching procedures must be employed. This type of point is itself rather difficult to grind and the absence of a center hole makes any reworking of the reamer a difficult job. This type of grind should not be specified when either of the grinds shown in Figs. 15 or 16 can be employed.

In general, if the grinds shown in figures 15, 16 and 17 are required, a reamer having straight or right hand spiral flutes should be chosen.

Fig. 18 shows a satisfactory method of regrinding the chamfer. The use of the bushing gives a very concentric chamfer in its relation to the outside diameter of the reamer. Fig 19 shows this same operation being done on the periphery of a straight wheel. This same operation can be performed between centers, and is shown in Fig. 20 using a cup wheel and in Fig. 21 with a straight wheel.

In order to obtain a concentric chamfer, the operator's fingers should hold the face of the flute against the locating finger with an even pressure. On those set-ups, where a bushing is used, the reamer should be pressed back lightly by hand against the tail stock center. It will be found best to rotate the grinding wheel so that it cuts from the face of the flute towards the back of the land, in order to reduce any tendency of the cutting edges to flake. The answer to the question as to whether a cup or straight wheel should be used will be determined to a great extent by the type of machine available. However, in general,

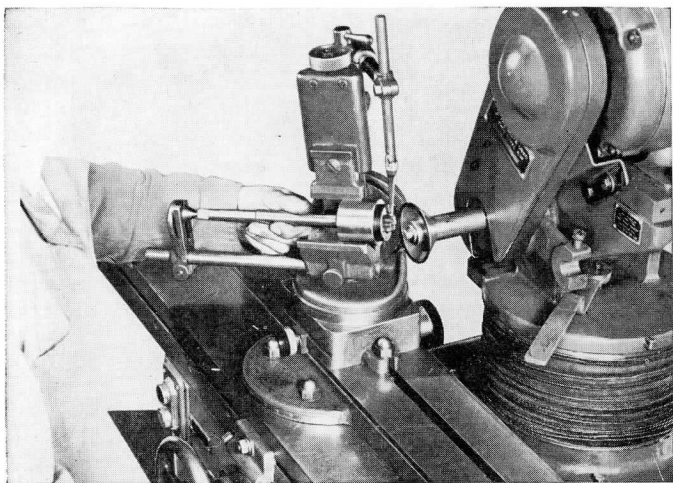


Fig. 18. Chamfering with use of a bushing employing a cup wheel

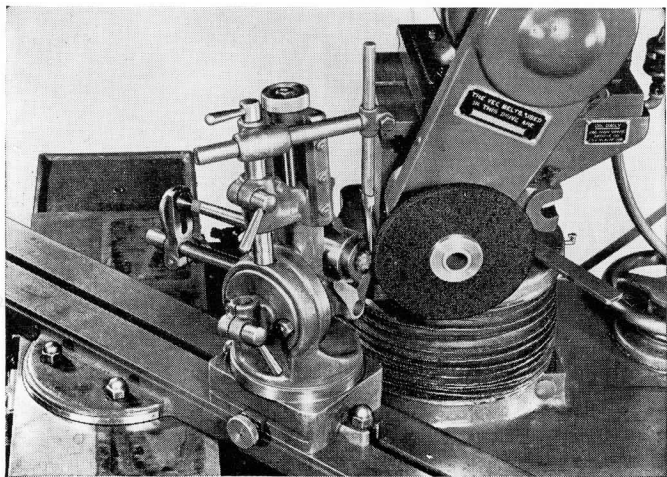


Fig. 19. Chamfering with use of a bushing employing a straight wheel

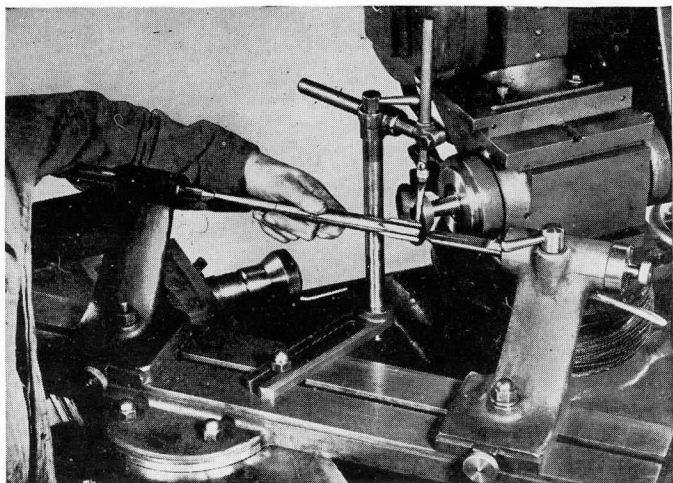


Fig. 20. Chamfering on centers with a cup wheel

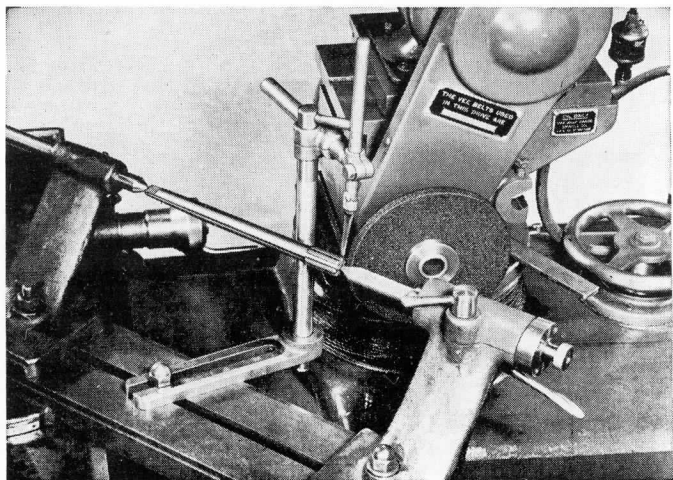


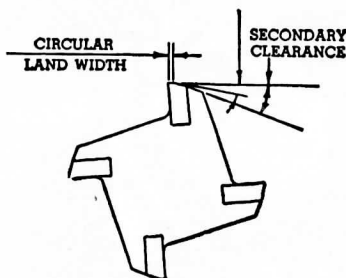
Fig. 21. Chamfering on centers with a straight wheel



the type of wheel to use should be the one which will allow the set-up to be as compact as possible, with a minimum amount of overhang. Clearance on the chamfers of reamers varies with the job; an angle of from 7° to 12° represents normal practice.

CIRCULAR LAND WIDTHS AND CLEARANCES

If it becomes necessary to regrind the diameter of a reamer, the lands must be cleared or relieved to prevent the reamer from binding in the hole. The best clearance angle and the best circular land width vary with the job, but the following table gives average figures.



Diameter of Reamer	Circular Land Width	Primary Clearance Angle
$\frac{1}{4}''$	.007"	14°
$\frac{1}{2}''$	.009"	11°
1"	.013"	9°
$1\frac{1}{2}''$	.016"	7°
2"	.023"	7°

A secondary clearance is usually ground on reamers as shown in the illustration above the table. This clearance is only to insure the back of the land being well away from the wall of the reamed hole, in order to prevent rubbing.



REGRINDING OF CARBIDE TIPPED REAMERS

In general, the cylindrical regrinding of Carbide Reamers should be done only when absolutely necessary. Usually only the chamfer will need regrinding, and two suggested methods for doing this will be found illustrated here. Occasionally, the face of the tips will need polishing slightly to remove any rounded edges or built-up portions. This can be accomplished by the method illustrated in Fig. 22.

The use of diamond wheels is recommended for regrinding these reamers. Grades having between 200 and 300

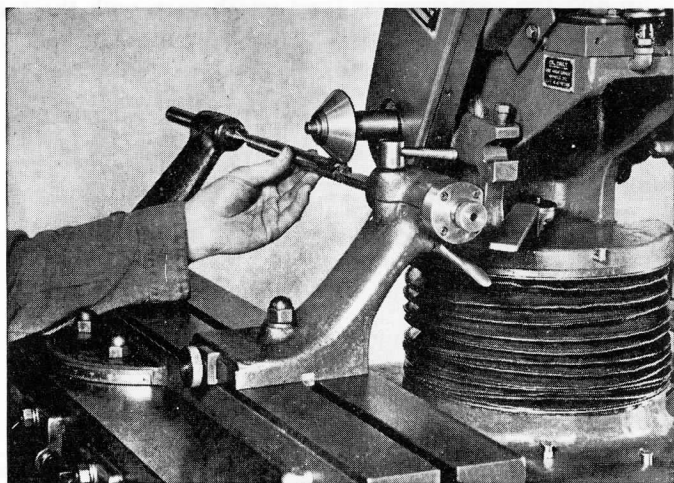


Fig. 22. *Regrinding Carbide Tipped Reamers*

grit perform satisfactorily; the wheel should be rotated so that it cuts from the face of the tip towards the back of the land, in order to minimize any tendency of the carbide to flake.

The clearance on the chamfers of Carbide Reamers is usually less than that used on High-Speed Steel Reamers, an angle of from 5° to 8° representing normal practice.



SUGGESTED METHODS FOR REGRINDING CHAMFER ON CARBIDE TIPPED REAMERS

The operation shown in Figs. 23 and 24, in two different set-ups, can be done equally well by substituting a cup wheel for the straight wheel shown.

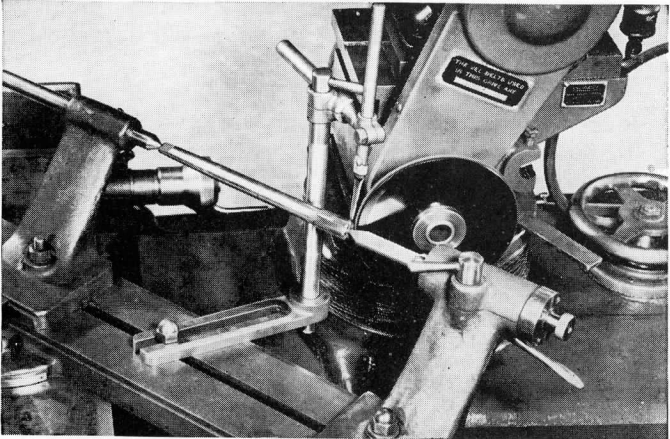


Fig. 23. A method using the periphery of a diamond wheel and the tool mounted between centers

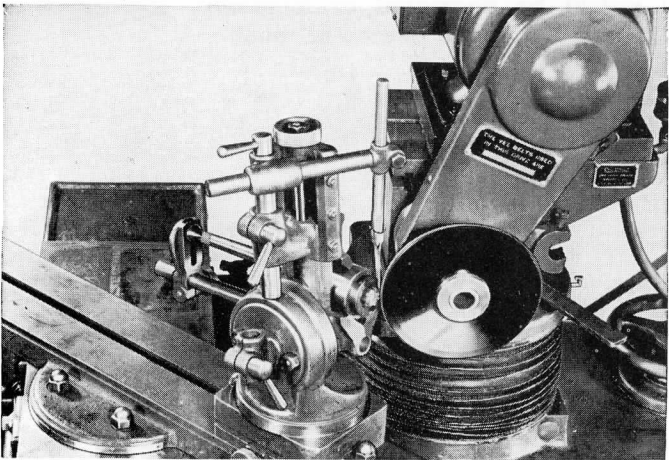


Fig. 24. A method which can be used when centers on the tool are no longer available



PROCEDURE FOR CHECKING RELIEF ANGLES

1. Mount the reamer between centers, using a bench center equipped with a sliding indicator post.
2. Adjust the vertical indicator to bear on the junction of the circular land and the primary relief as shown in Fig. 25.
3. Place another indicator below the vertical indicator on the same post to give a horizontal reading as the reamer is rotated. See Fig. 25.
4. Set up both indicators to bear on the reamer as shown, and rotate the reamer, reading the drop of the primary relief on the vertical indicator and the width of primary relief on the horizontal indicator.
5. This measured drop should be as shown in the accompanying table for a particular degree of clearance, diameter of reamer, and width of primary land. Should the land width become narrower or wider, the drop should be decreased or increased, respectively, to maintain a given degree of relief.

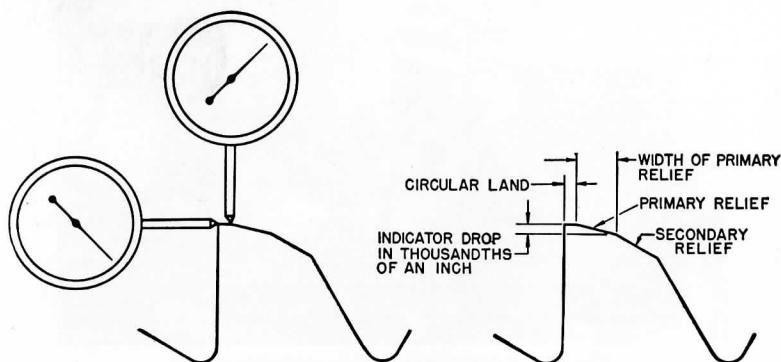


Fig. 25. Dial indicator used to check relief angles



Chart of Indicator Drop for Various Degrees of Standard Cutting Relief on Reamers

	Diam. of Reamer	Angle of Cutting Relief							
		5°	6°	7°	8°	9°	10°	11°	12°
For 1/64 width of Primary Clearance	1/8"	.0000	.0000	.0000	.0002	.0005	.0008	.001	.0015
	3/16"	.0000	.0004	.0006	.001	.0012	.0014	.0017	.002
	1/4"	.0004	.0007	.0009	.0012	.0015	.0018	.002	.0023
	5/16"	.0006	.0009	.0011	.0014	.0017	.002	.0022	.0025
	3/8"	.0007	.001	.0013	.0015	.0018	.0021	.0024	.0026
	7/16"	.0008	.0011	.0014	.0016	.0019	.0022	.0025	.0027
	1/2"	.0009	.0012	.0015	.0017	.002	.0022	.0025	.0028
	5/8"	.001	.0012	.0015	.0018	.0021	.0023	.0026	.0028
	3/4"	.0014	.002	.0025	.0031	.0036	.0042	.0047	.0053
	7/8"	.0017	.0022	.0028	.0033	.0038	.0044	.0049	.0055
	1"	.0018	.0023	.0029	.0034	.0039	.0045	.005	.0055
	1 1/8"	.0019	.0024	.003	.0035	.004	.0046	.0051	.0057
For 1/32 width of Primary Clearance	1 1/4"	.002	.0025	.0031	.0036	.0041	.0047	.0052	.0058
	1 3/8"	.002	.0026	.0031	.0037	.0042	.0047	.0053	.0058
	1 1/2"	.0021	.0026	.0032	.0037	.0043	.0048	.0054	.0059
	1 5/8"	.0021	.0027	.0032	.0038	.0043	.0048	.0054	.006
	1 3/4"	.0022	.0027	.0033	.0038	.0044	.0049	.0054	.006
	1 7/8"	.0022	.0028	.0033	.0038	.0044	.0049	.0054	.006
	2"	.0022	.0028	.0033	.0039	.0044	.0049	.0055	.006
	2 1/8"	.0023	.0028	.0034	.0039	.0045	.0049	.0055	.0061
	2 1/4"	.0023	.0029	.0034	.0039	.0045	.005	.0056	.0061
	2 3/8"	.0023	.0029	.0034	.004	.0045	.005	.0056	.0061
	2 1/2"	.0024	.0029	.0034	.004	.0045	.0051	.0056	.0061
	2 5/8"	.0024	.0029	.0035	.004	.0045	.0051	.0057	.0062
	2 3/4"	.0024	.0029	.0035	.004	.0045	.0051	.0057	.0062
	2 7/8"	.0024	.003	.0035	.004	.0046	.0051	.0057	.0062
	3"	.0024	.003	.0035	.004	.0046	.0051	.0057	.0062
	3 1/8"	.0024	.003	.0035	.004	.0046	.0051	.0057	.0062
	3 1/4"	.0024	.003	.0035	.0041	.0046	.0051	.0057	.0062
	3 3/8"	.0025	.003	.0035	.0041	.0046	.0051	.0057	.0062
	3 1/2"	.0025	.003	.0035	.0041	.0046	.0052	.0057	.0062
	3 5/8"	.0025	.003	.0035	.0041	.0047	.0052	.0057	.0062
	3 3/4"	.0025	.003	.0036	.0041	.0047	.0052	.0057	.0062
	3 7/8"	.0025	.003	.0036	.0041	.0047	.0052	.0057	.0063
	4"	.0025	.0031	.0036	.0041	.0047	.0052	.0057	.0063



The Care of Reamers

The quality of finish and the accuracy of the holes produced, as well as the ultimate life of a reamer, depend to a large extent on the treatment it receives. No discussion of reamers, therefore, is complete without considering this important factor.

The care of reamers should extend not only to the operation itself, but it is equally important that reamers are properly cared for while in storage, and during sharpening. With this in mind, some of the precautions that must be observed if the best results are to be obtained, are enumerated below. It should be kept in mind that a reamer is a finishing tool in every sense, that it is an expensive and comparatively short-lived tool, and that it is a delicate tool as compared with other tools used for roughing operations.

1. Never permit reamers to be stacked in bins or boxes without some separating layer of cardboard, wood, or the like. Individual cardboard tubes make excellent holders for reamers in storage. The edges are so hard and keen that even a light impact of the reamers against each other, or against some other hard object, will cause the edges to chip.
2. The same precautions should be observed when reamers are transported from the crib to the job and back and forth to the grinding room.
3. Provide a rack or suitable individual holder for reamers to be kept at the machine when not in use.
4. See that reamers are properly covered with oil when not in use, to prevent rusting at the cutting edges. Even a small rust spot will leave a pit or nick.
5. When resharpening, be sure to use a fine but free cutting wheel. Burning of the edge destroys the life of the reamer. A rough edge produces a rough hole, and the life of the reamer is shortened.

A careful observance of these few precautions will pay handsome dividends in any shop.



